

# Incorporating phylogeography for modelling the distribution of the carob tree (*Ceratonia siliqua*, Leguminosae) in future climate change.

Alex Baumel, Eleonora Potenza, Valentine Frelon, Juan Viruel, Gonzalo Nieto-Feliner, Magda Bou Dagher Kharrat, Lahcen Ouahmane, Hervé Sanguin, Stefano La Malfa, Mario Diguardo, Samuel Pironon, Jean-Pierre Suc, Nicolas Le Galliot, Frédéric Médail, Agathe Leriche.

The carob is an evergreen termophilous fruit tree widely harvested throughout the Mediterranean for food and forage since antiquity. Currently, the carob is found in cultivation in orchards or in association with other crops, and it has expanded towards industrial, agricultural and soil restoration purposes. Wild populations are found in shrublands, forests as well as rocky outcrops and temporary river banks.

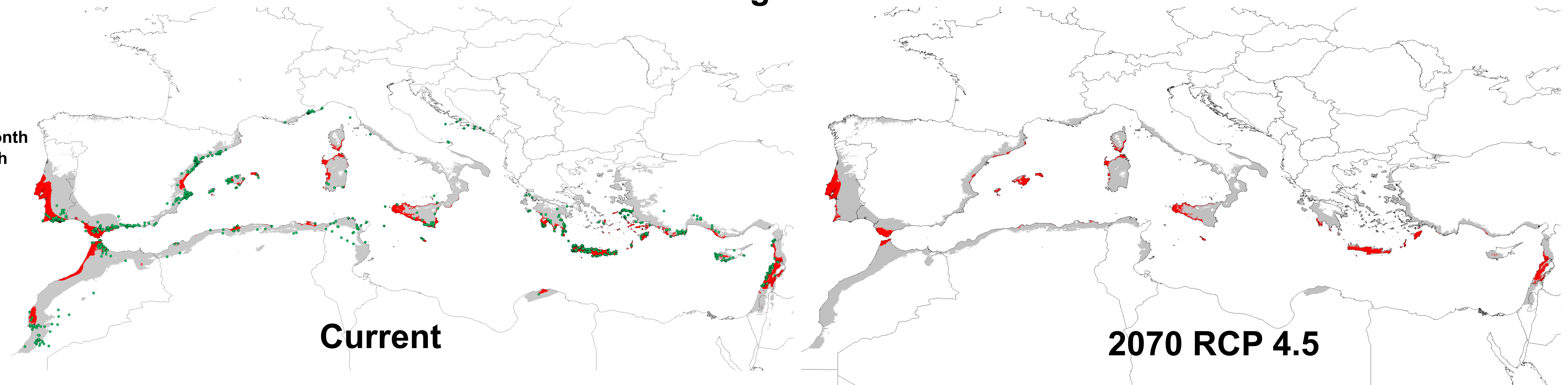


## Carob distribution modelling with Maxent

**759 points, 6 climatic variables,  
linear, quadratic and interaction features**

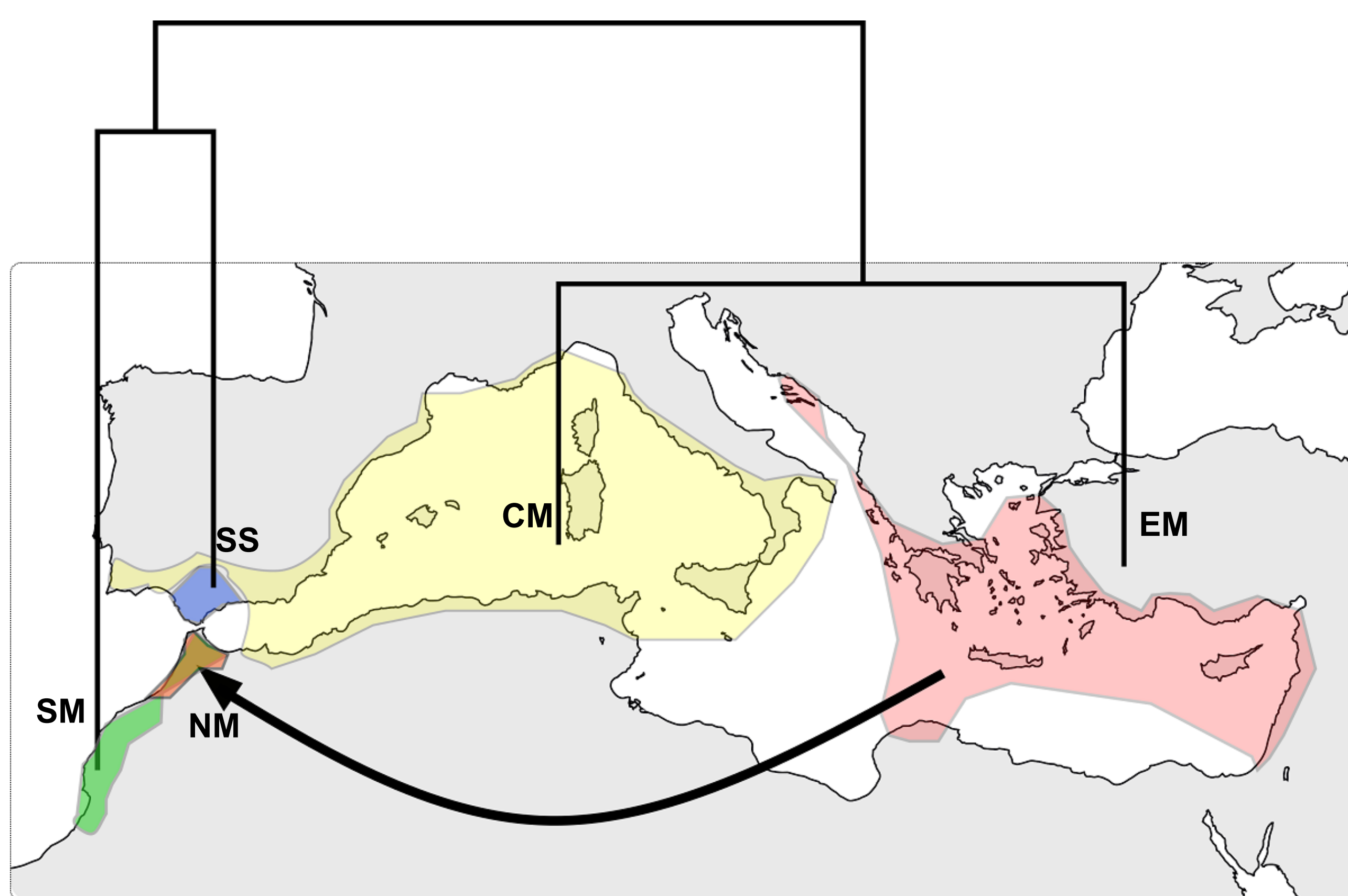
Selected climatic variables (Worldclim DB):  
 Annp: Mean annual temperature  
 Maxtwm: Maximum temperature warmest month  
 Mintcm: Minimum temperature coldest month  
 Psea: Precipitation seasonality  
 Twetq: Mean temperature of wettest quarter  
 Tsea: Temperature seasonality

Red : probability of presence 0.8-1  
Grey: probability of presence 0.25-1  
Green points: carob occurrences



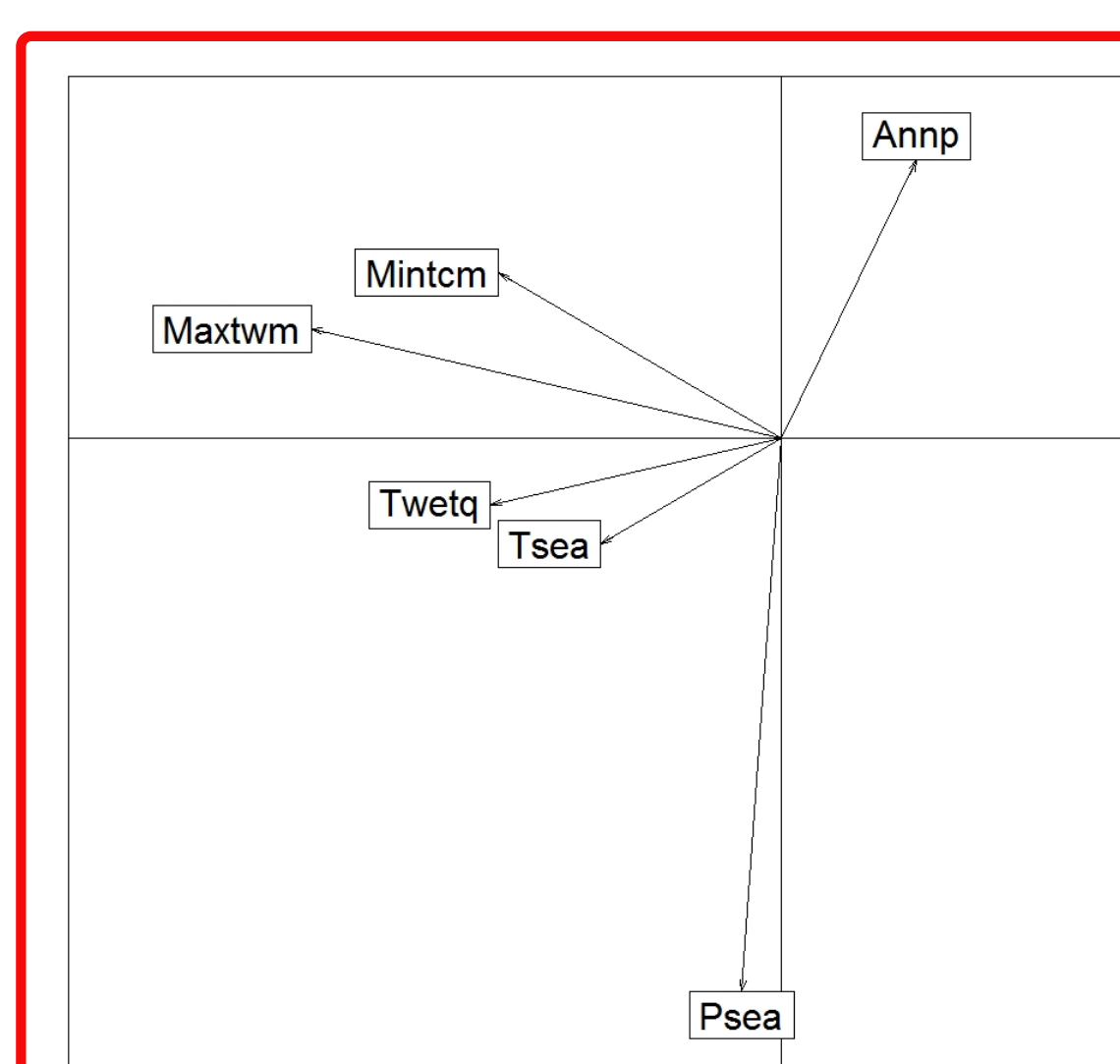
## Pessimistic forecasts?

## What happens if the climate niche is divided according to phylogeographic structure?



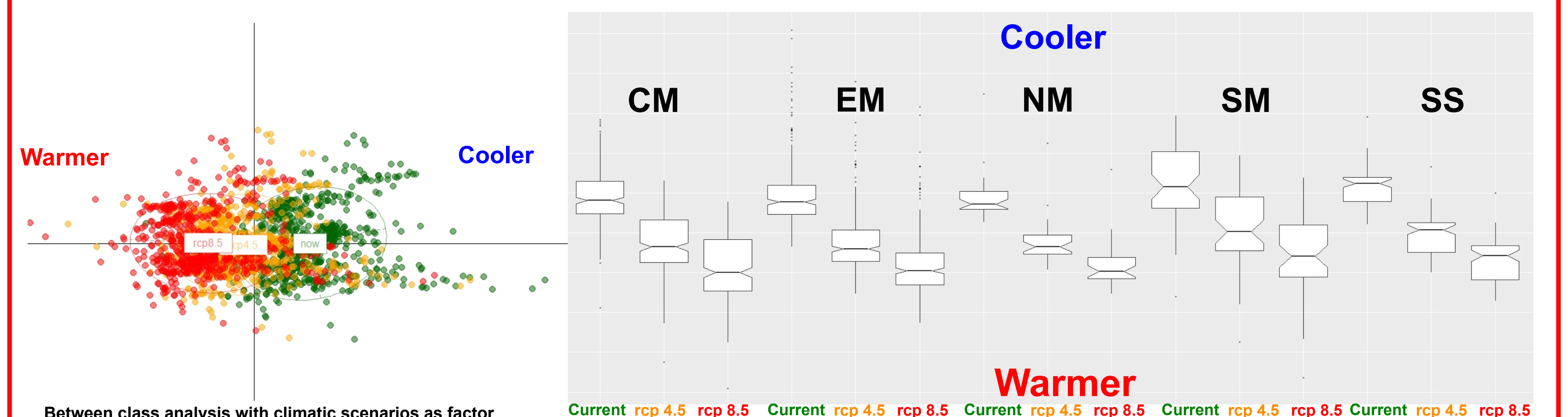
Carob phylogeography from Viruel et al. in press \*

Two distinctive lineages diverged after a strong historical bottleneck, which subsequently split in four genetic clusters across the Mediterranean (SM, South Morocco; SS, South Spain; CM, Central Mediterranean; EM, East Mediterranean). Admixture is frequent due to human dissemination, such as in the North Moroccan populations (NM) which show assymetric introgression between Eastern and Western genetic clusters.



### Analysis of the overlap between current and future (2070) climatic envelopes

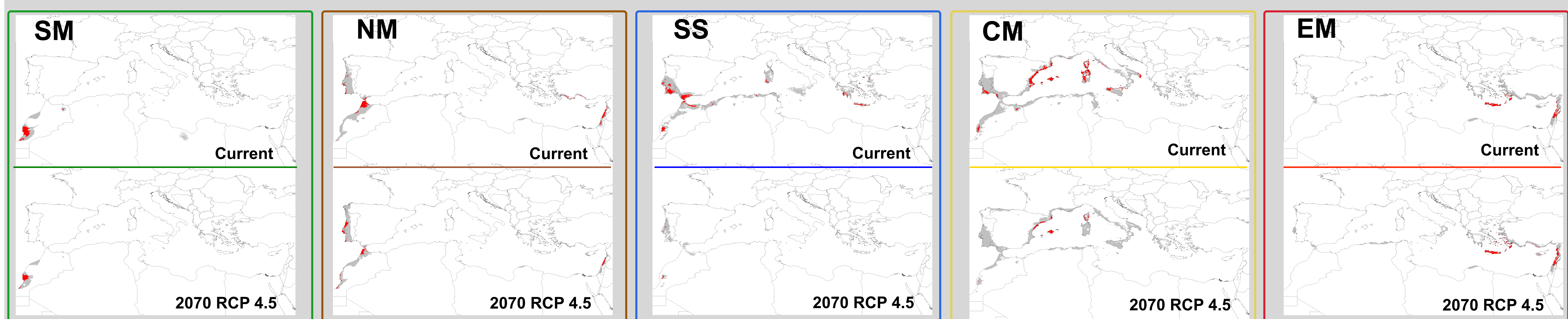
Data for the future were obtained by averaging the result of 3 GCM models (CNRM-CM5, HadGEM2-ES, CCSM4). Green, orange and red points correspond to the current period and to the RCP scenarios 4.5 and 8.5 respectively. A principal component analysis was done and used for a between class analysis (BCA) with the climatic change scenarios as factor. The first axis (BCA\_1) corresponding to temperature is the most correlated to climate change forecasting.



## How much change ?

**Box plots of the distribution on BCA\_1 axis of the five genetic clusters**

## New forecasting done with Maxent in respect to phylogeography and averaging results of 3 GCMs for RCP 4.5



**A range contraction in the Mediterranean is predicted for carob tree due to climate change. Overlap analysis of climatic niches as well as Maxent modelling indicate that incorporating phylogeography may improve carob distribution modelling and forecasting. In contrast with forecast done at the species level, the analyses done at the genetic groups level support SM, and EM as the most likely persistent areas whereas the most affected would be SS.**